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Derivation of I/M Benefits for Post-1980 Light Duty Vehicles for Low Altitude Non-California Areas

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Dave Hughes

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16. ABSTRACT

This report discusses the derivation of I/M benefits for the post-1980 Federal fleet as contained in EPA's emission factor model MOBILE2.

As is widely recognized, the post-1980 model year fleet will be predominantly composed of vehicles which employ what has become known as three way catalyst technology. This technology incorporates a sophisticated microprocessor-based engine control system which holds the air/fuel ratio very close to stoichiometry, thereby allowing the three way catalyst to simultaneously convert hydrocarbons (HC), carbon monoxide (CO) and oxides of nitrogen (NOx) to harmless by-products. As could be expected, such a significant shift in technology will have an impact on the expected in-use emissions performance of these vehicles both with and without an inspection and maintenance (I/M) program.

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I. Introduction.

As is widely recognized, the post-1980 model year fleet will be predominantly composed of vehicles which employ what has become known as Three Way catalyst technology. This technology incorporates a sophisticated microprocessor-based engine control system which holds the air/fuel ratio very close to stoichiometry, thereby allowing the Three Way catalyst to simultaneously convert Hydrocarbons (HC), Carbon Monoxide (CO) and Oxides of Nitrogen (NOx) to harmless by-products. This is in contrast to conventional technology vehicles (Model Years 1975-1980) which rely on mechanical control of the air/fuel ratio and whose catalysts are only designed to convert HC and CO. As could be expected, such a significant shift in technology will have an impact on the expected in-use emissions performance of these vehicles both with and without an Inspection and Maintenance (I/M) program.

This report discusses the derivation of I/M benefits for the post-1980 Federal fleet as contained in EPA's emission factor model MOBILE2*. As such, it relies heavily on an earlier report which presented the derivation of in-use emission factors (i.e. the emissions performance of the fleet without I/M) for the post-1980 Federal fleet [1].** It is recommended that the major structural points presented in that report be understood first, so that the analysis presented in this report can be more easily understood. This analysis will, however, briefly summarize how the in-use emission factors were derived.

Both this analysis and the emission factor analysis have relied on a modeling approach which structurally represents the trends observed in the data, as opposed to performing statistical analyses (e.g., linear regression with mileage as the independent variable) on large data bases as has traditionally been done for earlier model year fleets. This was done due to a lack of a sufficiently large data base on vehicles with representative Three Way catalyst systems. There is a substantial data base made up of Three Way catalyst systems which was closely examined to discern patterns of in-use performance and to examine the effectiveness of the various I/M short tests. That data base is not large enough, however, nor does it contain a sufficient mileage spread to enable the analyses required under the more traditional approach.

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* MOBILE2 is a computer program which models the emissions performance of the entire vehicle fleet over time, both with and without I/M. Figures of percent benefit due to I/M are applied to the without-I/M case in MOBILE2 in order to model the air quality impact of I/M.

** The numbers in brackets indicate references which will be listed at the end of the report.

The following sections will first present a brief description of the expected in-use performance of the post-1980 fleet. Second, the methodology and assumptions used in deriving I/M benefits for the post-1980 fleet will be presented and discussed. Finally, issues related to the use of the benefits contained in MOBILE2 will be discussed.

II. Expected In-Use Performance of the Post-1980 Fleet.

It is at this point that previous knowledge of the report which describes the derivation of emission factors for the post-1980 fleet would be of greatest advantage.[1] The following section will briefly summarize that derivation. As such, it discusses the expected modes of failure as opposed to presenting the emission factor equations themselves. A discussion of failure modes will be much more helpful in understanding how the I/M benefits were derived rather than presenting the emission factor equations.

The emission factor model first breaks the post-1980 fleet into two separate technology types: those vehicles which employ the Three Way catalyst technology described above, and those vehicles which rely on more conventional technology (oxidation catalysts, air pumps, engine modifications, EGR). This second group is expected to make up only 7% of the post-1980 fleet. This is a small fraction of the fleet, and its emission factors were derived differently than for the rest of the fleet. It would have been difficult to model I/M benefits for this group of vehicles because of the internal methodology used in deriving their emission factors. Given the small size of this group of vehicles, the added complexity that would have been necessary to include them in the calculation of I/M benefits, and the small increase in accuracy which would result, it was decided to ignore them in this analysis. Consequently, the results derived for the Three Way technology type have been assumed to be valid for these vehicles as well.

Of chief concern then is the group of vehicles equipped with Three Way catalyst technology. This group of vehicles was entitled "Closed Loop Vehicles" in the emission factor analysis, due to the nature of the microprocessor-based control system they employ. This system relies on a feedback signal from an oxygen sensor placed in the exhaust manifold which tells the microprocessor whether the air/fuel ratio is rich or lean of stoichiometry. The microprocessor uses this information in conjunction with information supplied by other sensors to adjust the air/fuel ratio at the carburetor. The system is therefore based on a "closed loop" form of control, with the signal from the oxygen sensor used to "close the loop". Three Way catalyst vehicles will therefore be referred to as Closed Loop vehicles for the rest of this analysis in order to parallel the terminology used in the emission factor analysis.

The emissions performance of Closed Loop vehicles was modeled by designating three distinct categories of emissions performance for HC and CO.* A data base of 218 in-use, Closed Loop vehicles was primarily relied upon to determine the incidence and the emission levels of the various categories. This data base is made up of the most representative and advanced Closed Loop technology vehicles for which data are currently available. (See Section II. of the emission factor analysis for a more complete discussion.[1])

The first category of vehicles represents those vehicles which have lost microprocessor control of the engine and are operating in a full-rich mode. This situation could result from a number of possible scenarios including microprocessor failure, tampering, sensor failures and disconnection of electrical wires. The failure scenarios possible will differ among the various manufacturers, but in all cases the end result is very high HC and CO emission levels. This category of vehicles is called the Primary category. This name was given because the vehicles in the Primary category, while not initially very numerous, contribute the majority of the fleet's in-use CO emissions and a large share of the in-use HC emissions. The emission levels attributed to the Primary category were based on data from ten in-use, low mileage Closed Loop vehicles from the data base which were observed to have a Primary category failure. The average emission levels of these vehicles were HC = 3.85 g/mi, CO = 108.0 g/mi at an average mileage of 9,163 miles. The Primary category was given an initial size of 3% of the fleet at zero miles and a growth rate of 2% per 10,000 miles. That is, as the fleet ages, more and more vehicles will experience the types of failures described above. (See Sections IV.A.2.a. and IV.A.3.a of the emission factor analysis for a more complete discussion.[1])

The second category of vehicles represents those vehicles which have experienced misfueling (that is, those vehicles equipped with catalytic convertors which have been fueled with leaded gasoline). The Misfueling category was modeled to make up 8% of the fleet based on the most recent EPA observations of misfueling in the field.[2] The HC and CO emission levels associated with vehicles in the misfueling category were derived from recent EPA misfueling test programs. They are well below the emission levels of Primary category vehicles but substantially above the emission levels of the remainder of the fleet. (See Sections IV.A.2.c and IV.A.3.c of the emission factor analysis for a more complete discussion.[1])

The third category of vehicles basically represents the remainder of the fleet. As such it includes both well-maintained vehicles and vehicles which have been tampered with or have suffered component wear or component failure, but not of the magnitude which would lead to the Primary category. The emission levels associated with this category were based on data from over 190 in-use, low-mileage Closed Loop vehicles from among the data base described above. This category is referred to as the Secondary category. (See Sections IV.A.2.b and IV.A.3.b of the emission factor analysis for a more complete discussion.[1])

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* The NOx analysis was performed separately and will be briefly discussed in the next section.

The fleet therefore is broken down into three categories of vehicles for the HC and CO analysis, each category with a distinct emissions performance. Each category has a unique zero mile emission level and there is a common deterioration rate used for all the categories for a given pollutant. The deterioration rates were developed for the Secondary category and then adopted for the Primary and Misfueling categories. This was done due to a lack of enough separate data for the Primary and Misfueling categories to be able to predict a unique deterioration rate for those categories. As could be expected from the preceding discussion, it is chiefly the number of vehicles entering the Primary category with its very high HC and CO emission levels, and not the deterioration rates, which is of foremost concern from an I/M perspective. The following section will present how the I/M benefits were derived.

III. Methodology Used in Determining I/M Benefits.

Basically two separate phenomenon were accounted for in calculating I/M benefits for the post-1980 fleet: the identification of Primary category vehicles and the identification of vehicles experiencing severe ignition and misfire problems.

One issue that needs to be addressed before proceeding has to do with which model year case of the emission factor analysis was used to determine I/M benefits.[1] Those readers familiar with the emission factor analysis will note that three separate cases were modeled for the post-1980 fleet: the 1981 model year fleet, the 1982 model year fleet and the 1983 and beyond model year fleet. Separate analyses were required for 1981 and 1982 due to the presence of the Clean Air Act Section 202(b)(5) waiver fleet: those cars that received a waiver of the CO standard from 3.4 g/mi to 7.0 g/mi in 1981 and 1982. 1981 and 1982 are also the model years when the benefits which accrue from the Parameter Adjustment regulations (44 F.R. 2960) are phased into the model. The differences between the various model year cases are not great. The 1983 and beyond case was used as the base case in determining I/M benefits. This was because the 1983 and beyond case is the most representative case for the overall timeframe for which I/M benefits need to be calculated. It would have added a significant measure of complexity without an appreciable gain in accuracy to account for the small differences in the 1981 and 1982 model years.

A. Identification of Primary Category Vehicles.

The only significant issue involved here is what percentage of Primary category vehicles can be expected to be identified by the various I/M short tests. Since Primary category vehicles emit such high levels of HC and CO and indeed contribute the majority of the overall fleet's in-use CO emissions and a large share of the fleet's HC emissions, it is reasonable to expect that an I/M short test be capable of identifying most of these vehicles. This is especially true if excess emissions (i.e. emissions above the Federal standards) are considered instead of total emissions. Primary category vehicles contribute an overwhelming share of the excess emissions, which are of chief concern from an I/M perspective. The ability of the various short tests to identify Primary category vehicles was quantified by examining short test data from the ten in-use Primary category vehicles mentioned earlier. Table III.A.1. presents the results of applying the inspection cutpoints

consistent with the emissions performance warranty (mandated by Section 207(b) of the Clean Air Act) to the short test data. The individual data from each of the 10 vehicles is presented in Appendix A.

Table III.A.1
Ability of the Various Short Tests to Identify Primary Category Vehicles

Short Test	Applicable Cutpoints	Percent of Primary Category Vehicles Identified*
Idle(N)	1.2% CO, 220 ppm HC	50%
2500 rpm/Idle(N)	1.2% CO, 220 ppm HC	60%
Loaded Two Mode (30 mph/Idle(N))	1.2% CO, 220 ppm HC	70%

At first inspection, Table III.A.1 suggests definite incremental benefits in going from the Idle(N) test to the 2500 rpm/Idle(N) test to the Loaded Two Mode test. A closer inspection, however, reveals that making a distinction between the 2500 rpm/Idle(N) and Loaded Two Mode tests on the basis of the data currently on hand is unwarranted. As can be seen in Attachment A, one vehicle, the second 1979 Mercury Marquis, "passed" the 2500 rpm/Idle(N) by only 0.02% CO. Given the fact that this one vehicle was only a very marginally "passing" vehicle and given the fact that previous examinations and technical judgement do not support a significant distinction between the 2500 rpm/Idle(N) test and the Loaded Two Mode test, EPA has decided to associate a 70% Identification Rate of Primary category vehicles with the 2500 rpm/Idle(N) test. That is, the Loaded Two Mode and 2500 rpm/Idle(N) tests are judged to be equally capable of identifying Primary category vehicles - at a 70% Identification Rate. The selection of an Identification Rate to be associated with a given short test is significant in terms of the emission benefits which result from the model. The significance of the Identification Rate of Primary category vehicles will become more apparent as the report progresses. In summary, given the limited data available, it is not warranted to make distinctions of such consequence where previous experience and technical judgement do not support the distinction.

* This quantity, the percent of Primary category vehicles identified by a given short test, is referred to as the Identification Rate in the "User's Guide to the Mobile Source Emissions Model: MOBILE2". Section 2.2.4 of that report discusses the Identification Rate.

50% was used as the default value within MOBILE2 for the Identification Rate of Primary category vehicles in the calculation of I/M benefits. As can be seen in Table III.A.1. this is the Identification Rate associated with the basic Idle(N) test. Section 4 of this report will deal with the inner workings of MOBILE2 and the use of alternate Identification Rates in greater detail.

Identification Rates of 60%, 70%, 80% and 90% were also evaluated and incorporated into MOBILE2 to provide flexibility for those states and localities who choose to use the Loaded Two Mode test or the Idle(N)/2500 rpm test, and also to provide flexibility for modifications if the addition of more data at a later point changes the percent of Primary category vehicles identified by the various short tests.

Those Primary category vehicles which are modeled as being identified in the I/M process are all assumed to be repaired. The emission levels of the repaired vehicles were modeled by assuming 8% of the repaired vehicles enter the Misfueling category and adopt the Misfueling category's emission levels. The rest are assumed to adopt the emission levels of the Secondary category. Eight percent are modeled to enter the Misfueling category since the overall misfueling rate of 8% is assumed to occur uniformly throughout the fleet. Therefore 8% of the vehicles in the Primary category have also experienced misfueling. When these vehicles are repaired, the engine control system is returned to normal operation but the catalyst (and oxygen sensor) will still be damaged due to misfueling. Thus, these vehicles should be assigned emission levels which reflect a history of misfueling.

Primary category vehicles which are not identified by the I/M short test at a given inspection are assumed to also not be identified at all subsequent inspections. For example, the 50% of Primary category vehicles not identified at the first round of inspections in the default case will thereafter always remain in the fleet as Primary category vehicles. This reflects the assumption that some Primary category failure modes will have low emissions at the operating points tested by the given short test and are not capable of ever being identified by that short test. This assumption is conservative (results in lower benefits from the I/M program) relative to the possible competing assumption that some Primary vehicles (50% in the default case) are able to pass a given inspection due to a random process which occurs independently at each inspection. No evidence exists to support or contradict this less conservative assumption.

Those Primary category vehicles which are identified and repaired in the I/M process are subsequently assumed to be eligible to reenter the Primary category at the same rate as other vehicles in the fleet. These vehicles are <u>not</u> exempt from ever entering the Primary category again. This is because of the number and variety of scenarios which can lead to Primary category operation as well as due to the effects of change of ownership in conjunction with tampering by a new owner.

It should also be noted at this point that the likelihood of a vehicle entering the Primary category is modeled as slowly increasing as a vehicle accumulates mileage. That is, as a vehicle ages, it is more likely to

experience a Primary category failure, due to increased component wear and decreased incentive for the owner to properly maintain his vehicle. This was modeled by relying on the Primary category growth rate used in the emission factor analysis. A "constant" 2%/10,000 mile growth rate was used in that analysis, but since the 2% is coming from an ever smaller group of non-Primary category vehicles, the assumption of a constant rate implies an increasing likelihood of Primary category failure as a vehicle ages. For example, at zero miles, 97% of the fleet is not in the Primary category and out of this group 2% of the total fleet enters the Primary category over the first 10,000 miles. At 100,000 miles, only 77% of the fleet is not in the Primary category, yet the same number of vehicles, 2% of the total fleet, enters the Primary category over the next 10,000 miles. Thus, the emission factor analysis models an increasing likelihood for a vehicle to enter the Primary category as it ages. The algorithm which describes this tendency was used to determine the growth of the Primary category between inspection points for the calculation of I/M benefits.

The failure rate of Primary category vehicles (not to be confused with the Identification Rate) will be low, especially after the first years of an I/M program's implementation. This is due to the fact that the growth rate of the Primary category is modeled to be only 2%/10,000 miles. There are therefore simply not that many Primary category vehicles to identify, although identifying the ones present in the field results in substantial emission benefits. Table IV.A.1 includes an example of the expected failure rate of Primary category vehicles.

The identification of Primary category vehicles in the I/M process accounts for all of the CO benefits contained in MOBILE2 and roughly half of the HC benefits. The HC benefits resulting from the identification of Primary category vehicles cannot be presented exactly since they were calculated in conjunction with the HC benefits which result from the identification of vehicles with ignition/misfire problems. A summary of total benefits will be presented later. To give the reader an indication of the magnitude of the benefits resulting from the identification of Primary category vehicles, for the default case (50% Identification Rate corresponding to use of the basic Idle(N) test) the CO benefits are approximately 30% after the first year of program implementation and the HC benefits are approximately 15%. These figures of percent benefit represent the percent of emissions reduction attributed to I/M as compared to the base case (without I/M).

NOx Penalty Issue.

The reader may wonder if there should not be a NOx "penalty" associated with the HC/CO "benefits" which accrue from the repair of Primary category vehicles. This would be because of the very low NOx emission levels which result when a vehicle is in the Primary category's rich mode of operation. Low NOx levels result in this situation due to two parallel phenomenon: the low NOx levels which are always produced by an engine during rich modes of operation and the increased NOx conversion efficiency of the Three Way catalyst during rich operation. The emission factor analysis accounted for the low NOx levels of Primary category vehicles by creating a separate NOx category, the Low category, which parallels the growth of the Primary category

(See Section V.A. of the emission factor analysis for a complete discussion[1]). It stands to reason that when Primary/Low category vehicles are repaired, the low NOx emission levels will rise as the HC/CO emission levels fall. Thus, a theoretical NOx "penalty" results from I/M. This issue was examined in a similar fashion as was done in developing the HC/CO credits for identifying Primary category vehicles. A model was constructed wherein Low category vehicles were identified and repaired. A comparison was then made between the with and without I/M cases. The results of that analysis showed only a very small NOx penalty. In a "worst-case" scenario which set the upper bound for a possible NOx penalty, the "percent penalty" was only 2% at 50,000 miles and 2.7% at 100,000 miles. The reason why the NOx "penalty" is so small whereas the HC/CO benefits are fairly large (15%/30%) has to do with the difference between the category emission levels for HC/CO as compared to NOx, and the difference between the contribution of the category deterioration rates for HC/CO and NOx. For HC and especially for CO, the gap between the emission levels of the Primary category and the other categories is much larger than between the NOx Low category and the other NOx categories. Thus there is less difference for NOx before and after repair when the repaired vehicles enter a new category and therefore a small "penalty" results. Also for NOx the deterioration rates of the various categories play a much larger role in determining the fleetwide composite. Therefore shifts between categories are much less significant. Given the small size of the NOx penalty and realizing that identifying so small a percentage would be overstepping the inherent accuracy of the model, the NOx penalty issue was ignored.

B. Identification of Vehicles With Ignition/Misfire Problems.

Ignition and misfire problems have historically been the cause of a significant portion of excess HC emissions. While a modeling approach such as has been used in this analysis cannot accurately account for the emissions impact of every possible vehicle malfunction, ignition/misfire problems were judged to have a significant enough impact on in-use HC emissions that they should be accounted for. Post-1980 vehicles can be expected to be free of many historical maladjustments (e.g. idle mixture) due to technology changes but will still be prone to ignition/misfire problems. Post-1980 vehicles will still experience shorting and cracking of ignition wires, spark plug failures, cracking of distributor elements etc., all of which will lead to excessive HC emissions. These types of failures are readily identifiable by the various I/M short tests since they usually result in greatly increased HC emissions at all modes of operation.

A final introductory point which needs to be made is that ignition/misfire problems are assumed to occur in proportion to vehicle age. That is, as a vehicle ages, it has a greater likelihood of experiencing an ignition/misfire problem. This point is significant in that it largely determined which data could best be used to examine the I/M benefit resulting from the identification of vehicles with ignition/misfire problems. In particular, data confined to small mileage intervals are not suitable.

Methodology.

There is an important difference in the way benefits were calculated for the identification of vehicles with ignition/misfire problems as opposed to the identification of Primary category vehicles. The presence of Primary category vehicles (i.e. vehicles with a failure of the computer control system with a resultant rich mode of operation) among the fleet was clearly delineated in the emission factor analysis through the establishment of a category. The category grows with time (in the absence of I/M) and its size and therefore its effect can be calculated at any point by knowing the category growth rate. The calculation of I/M benefits for these vehicles was therefore fairly straightforward, since the presence of these vehicles in the fleet is so clearly delineated.

The emission factor analysis did not account for the impact of vehicles with ignition/misfire problems by creating a corresponding "ignition/misfire" category, however. Rather, it accounted for the impact of these vehicles implicitly through the HC zero-mile emission levels assigned to the Secondary and Misfueling categories and the HC deterioration rate used for all categories.* Repair of ignition/misfire problems in an I/M program is modeled by adjusting deterioration rates, rather than by adjusting the distribution of vehicles among categories. The number of vehicles failing the I/M test due to misfires and their HC emission levels have not been modeled directly; only their effect on the average emissions of all vehicles in a given category (Primary, Secondary, or Misfueled) appears in the model.

The Volvo/Saab fleet described in Section II.D. of the emission factor analysis played the major role in determining the I/M benefits resulting from the identification of vehicles with ignition/misfire problems[1]. This fleet contains 104 1978/1979 Volvos and Saabs which all met the criteria established to screen out those vehicles with maladjustments which can be expected to be

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* The HC zero-mile emission level assigned to the Secondary category was based on data from 191 representative, in-use vehicles. One of these, a 1980 General Motors six cylinder Citation with 12,879 miles, had its number 1 cylinder shorted in the distributor cap. FTP HC emissions from this vehicle were 4.8 g/mi. This one vehicle contributed 8% of the average HC emission level of the 191 vehicles in the Secondary category data base. The impact of this vehicle was also carried over into the Misfueling category since the zero-mile emission level of the Misfueling category was arrived at by applying a multiplicative factor to that of the Secondary category.

The HC deterioration rate used for the various categories is also assumed to include the effects of vehicles with ignition/misfire problems. That is, part of the deterioration rate is attributed to the increasing presence of vehicles with ignition/misfire problems and correspondingly high HC emission levels. These problems are assumed to occur more frequently at higher mileage, thereby adding a "misfire" component to the deterioration rate.

prevented by the advent of EPA's "Parameter Adjustment" regulations (44 F.R. 2960). The Volvo/Saab fleet was used due to its having a wider mileage spread than the other Closed Loop vehicle fleets. The presence of a wide mileage spread was considered necessary in order to better see the effects of the increasing likelihood of vehicles to experience ignition/misfire problems as they accumulate mileage. The calculation of I/M benefits was done in the following manner. First, the data from the Volvo/Saab fleet was put through an I/M simulation where vehicles were identified by only using an HC cutpoint of 200 ppm. The I/M short test used as the basis of evaluation was the Idle(N)/2500 rpm test where emissions are measured and evaluated at both Idle(N) and 2500 rpm. This short test is expected to receive wide use for post-1980 vehicles. A cutpoint of 200 ppm HC was used. Putting the fleet of 104 Volvos and Saabs through the I/M simulation resulted in 2 vehicles being identified as failures. The mean HC emissions of these two vehicles was 4.18 g/mi at an average mileage of 15,365 miles. One vehicle seemed to be experiencing intermittent misfire and the other had a failed spark plug. Both of these cars would have only been identified using the HC cutpoint. That is, they would not have been failed by a corresponding CO cutpoint of 1% CO. They were classic HC-only failures.

The second methodological step in determining ignition/misfire benefits involved developing a deterioration rate for the various categories without the presence of vehicles with ignition/misfire problems. That is, assuming that an I/M process would identify these vehicles as requiring maintenance, what would the HC deterioration rate be without their presence. This was done by calculating the percent reduction due to removing the two vehicles described above. This percent reduction was then applied to the HC emission factor equation developed for the Secondary category of Closed Loop vehicles: HC = 0.23 g/mi + 0.12 g/mi/10,000 miles x (Miles/10,000) (See Section IV.A.2.b. of the emission factor analysis [1]).* The percent reduction was applied at the Volvo/Saab fleetwide average mileage of 13,786 miles. This determined one point on the new line. A second point on the line was chosen to be the zero mile level of the HC emission factor equation for the Secondary category: 0.23 g/mi. This was done even though this point reflects the presence of a vehicle with ignition/misfire problems as discussed above (the Citation with a cylinder shorted in the distributor cap), due to the fact that the I/M process would not begin to identify these vehicles until their first inspection at one year of age (approximately 14,000 miles).

Table III.B.1. presents the pertinent values used in the above development and Figure III.B.1. presents a graphical illustration of the concept.

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* Since the Volvo fleet most closely resembles a fleet of Secondary category vehicles, the new HC deterioration rate was calculated using the Secondary category's emission performance as a base. The new rate was then applied to the Primary and Misfueling categories as well. Primary and Misfueling category vehicles are expected to experience ignition/misfire problems at the same rate and with the same proportional effect as Secondary category vehicles.

Figure III.B.1.

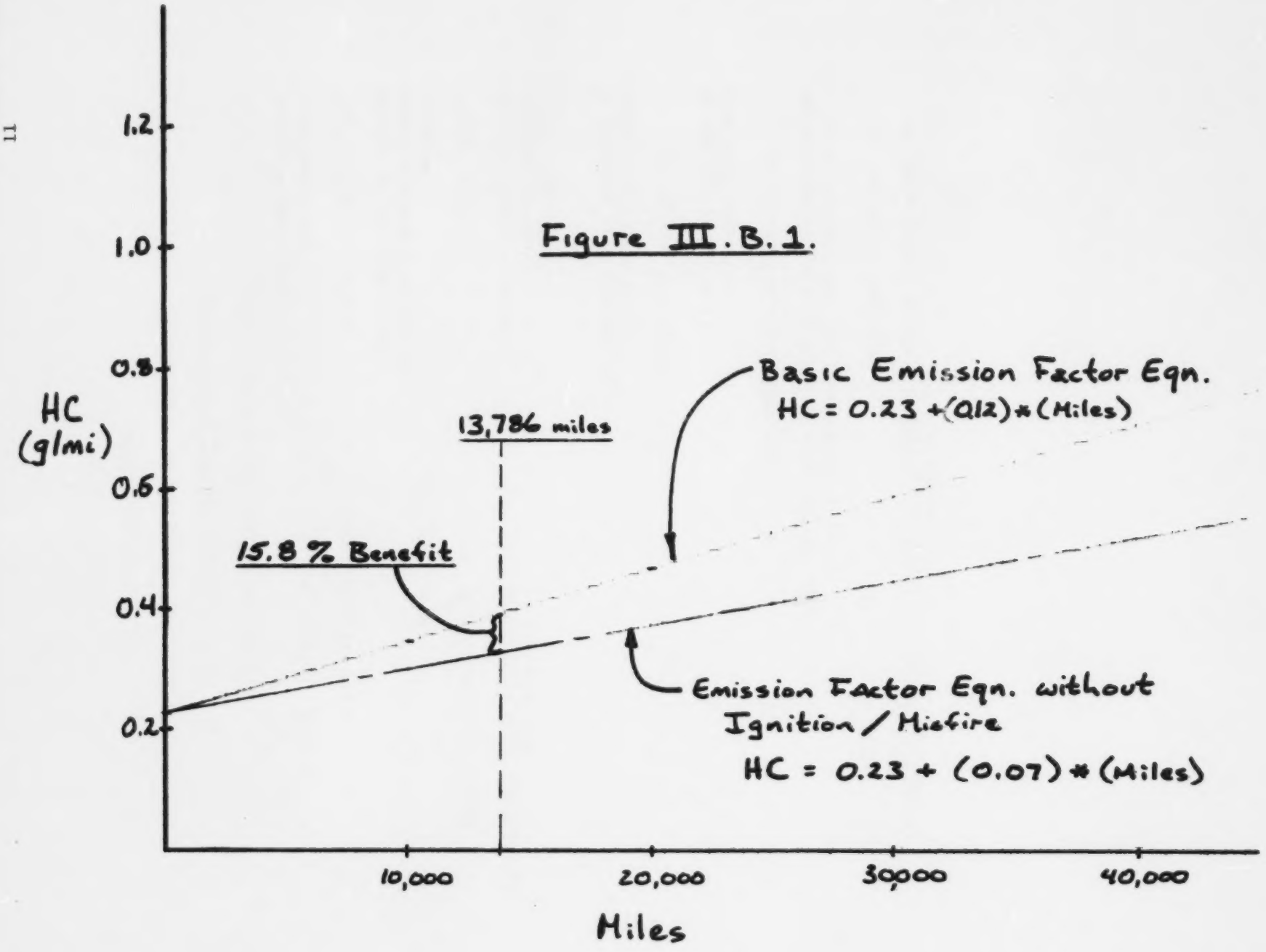


Table III.B.1.

Values Used in the Development of an HC Deterioration Rate Without the Presence of Vehicles with Ignition/Misfire Problems

Average HC emissions of total Volvo/Saab fleet	= 0.462 g/mi (n=104)
Average fleetwide mileage	= 13,786 miles (n=104)
Average HC emissions without vehicles with ignition/misfire problems	= 0.389 g/mi (n=102)
Percent reduction	= (0.462 - 0.389/0.462)x100 = 15.8%
Emission factor equation of Secondary category Closed Loop vehicles[1]	HC = 0.23 g/mi + (0.12 g/mi/10,000 miles)* (miles/10,000)

HC emission level from the above equation at 13,786 miles:

HC = 0.23 g/mi + (0.12) * (13,786/10,000) = 0.395 g/mi

HC emission at 13,786 miles with 15.8% reduction:

HC = 0.395 - (0.158)(0.395) = 0.333 g/mi

New Emission Factor Equation accounting for the identification of vehicles with ignition/misfire problems:

a. Zero-Mile = 0.23 g/mi

b. Deterioration Rate = $\frac{0.33 \text{ g/mi} - 0.23 \text{ g/mi}}{13{,}786 \text{ miles}}$ = 0.07 g/mi/10,000 miles

The reason why a regression analysis was not performed on the Volvo/Saab fleet after removing the vehicles with ignition/misfire problems can best be understood by considering the development of deterioration rates for the Secondary category as presented in Section IV.A.2.b. of the emission factor analysis[1]. The reader will note that although a regression analysis of the complete Volvo/Saab fleet was performed in that development (after deletion of some cars for parameter maladjustment), the result was not applied for the HC case. Instead, the result for CO (the ratio between in-use performance and Certification performance) was used to replace the HC results because the latter was judged to be unreliable.

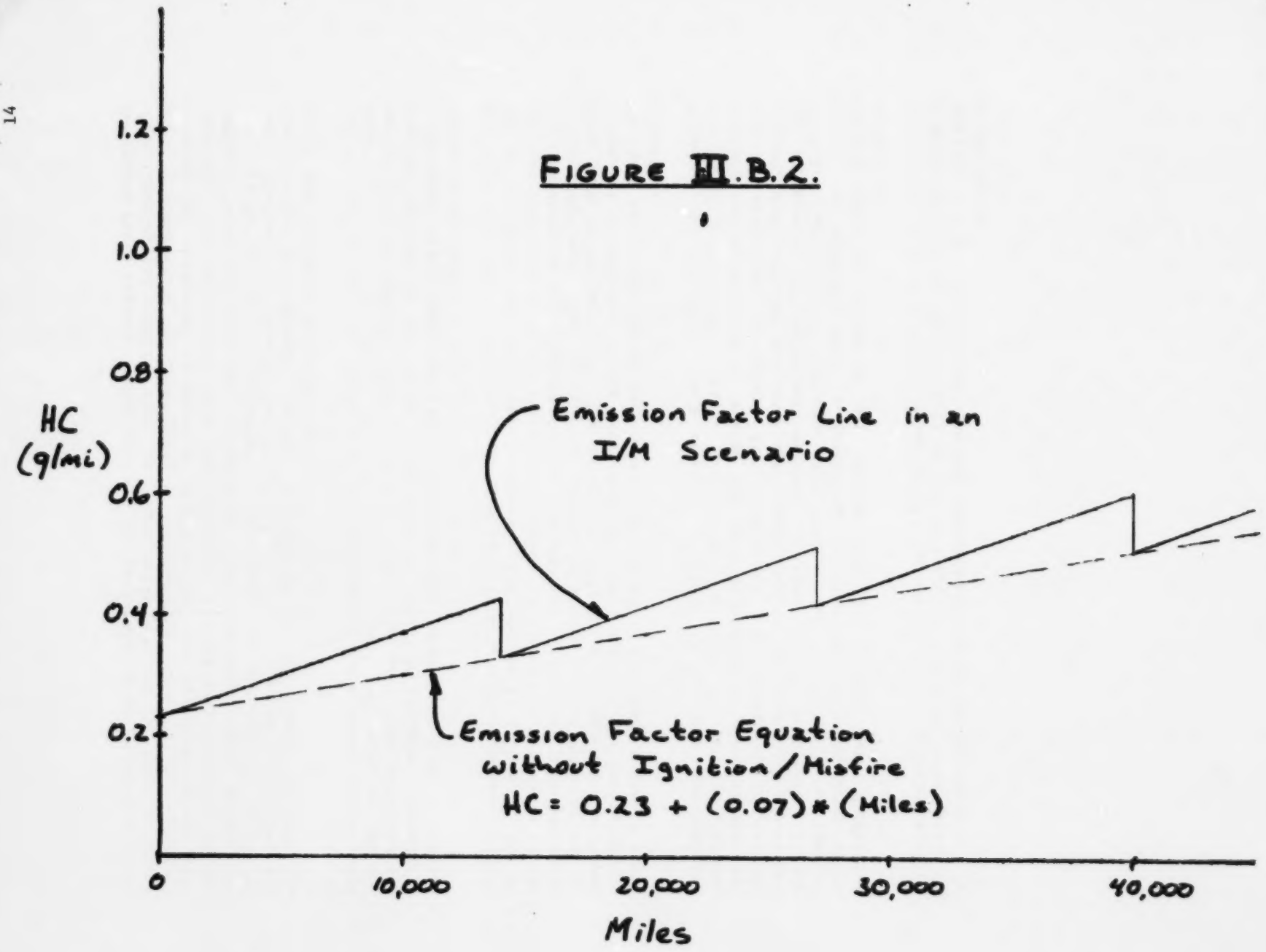
The end product of this portion of the development is a deterioration rate which represents the average HC deterioration of post-1980 vehicles without the presence of vehicles with ignition/misfire problems. This deterioration rate is applied to all three categories of vehicles (Primary, Secondary, Misfueling) since ignition/misfire problems are assumed to have a similar impact on all three.

The third and final methodological step is fairly straight-forward. Simply put, at the first inspection point after the I/M process is initiated, the HC emission performance of the various categories is assumed to drop down to the line representing the category without the presence of vehicles with ignition/misfire problems. That is, I/M is assumed to identify those vehicles and to cause them to be repaired. The emissions performance of <u>each</u> of the three categories of vehicles in the fleet drop down to a new line for the category. The three categories can of course be simply weighted together to give a fleet composite.

Following the inspection, each category readopts its previous deterioration rate (0.12 g/mi/10,000 miles). This is because after the I/M inspection, vehicles can be expected to develop new ignition/misfire problems at the same rate of occurrence as before the inspection. At subsequent inspections however, each category will once again drop down to the line which represents the category's HC emissions without ignition/misfire problems. Figure III.B.2. graphically illustrates this concept for the first three inspections. It examines what is happening for the Secondary category only. Exactly parallel scenarios are modeled for the Primary and Misfueling categories.

The I/M benefits which accrue from identifying vehicles with ignition/ misfire problems account for roughly half of the HC benefits contained in MOBILE2. CO benefits for this phenomenon were not addressed since it is overwhelmingly a HC phenomenon.

FIGURE III.B.2.



IV. Post-1980 Model Year I/M Benefits as Contained in MOBILE2.

A. Introduction.

The preceding sections presented the assumptions and methodologies used to model the impact of an Inspection/Maintenance program on the post-1980 fleet's emissions. These assumptions and methodological steps were incorporated into a computer model which tracked the fleet through an Inspection/Maintenance program over time. This was done in order to calculate actual figures of the percent benefit due to I/M (i.e. the percent reduction in HC/CO emission levels due to I/M). A detailed discussion of the computer model will not be given here, although a copy of the computer program is attached. (Appendix B). The computer program simply incorporates the methodology developed in this report.

The output of the program is a series of large matrices. Each matrix contains the benefits which are modeled to accrue for a given Identification Rate of Primary category vehicles. Each matrix has nineteen rows of benefits. These rows contain the benefits which are modeled to accrue for an I/M program starting-up in any of the nineteen calendar years following a given model year. The computer program is based on an assumption that the maximum life of a vehicle is 20 years. Therefore as the start-up of an I/M program comes later and later than the introduction of a given model year, the number of years for which I/M benefits are calculated steadily decreases. For example, for the 1981 model year fleet, if the I/M program begins in January of 1983, I/M benefits need to be calculated for the following 18 years. If the I/M program doesn't begin until January of 1990, however, 1981 model year vehicles would only be active participants of the program for 11 years. There would therefore only be a need to calculate benefits for 11 years in that case.

The output of the computer program presented in Appendix B. then, is a series of matrices which provide the HC and CO benefits due to I/M under a wide variety of scenarios. These scenarios are determined by the Identification Rate of Primary category vehicles and the year of I/M program start-up in relation to the model year. Table IV.A.1 presents an example of the benefits stored in one of the matrices. This example gives the benefits resulting from using the default Identification Rate of 50% and with the I/M program starting-up in the first year of a model year. The total array of benefits as contained in MOBILE2 will not be presented due to its size. Table IV.A.1 also presents the failure rate of Primary category vehicles resulting from the above scenario. It should be noted that this failure rate does not include the identification of vehicles with ignition/misfire vehicles. These vehicles can be expected to contribute between 2% and 6% to an I/M program's failure rate, especially as given model year fleets age.

Table IV.A.1.

Post-1980 I/M Benefits for a 50% Identification Rate and Program Start up in the First Year Of a Model Year

Benefit Year	Primary Category Failure Rate*	HC Benefit*	CO Benefit*
1	3	8	9
2	1	23	28
3	1	28	30
4	1	31	31
5	1	33	31
6	1	35	32
7	1	36	32
8	1	36	32
9	1	37	32
10	1	37	32
11	1	38	32
12	1	38	32
13	1	38	32
14	1	38	32
15	1	39	32
16	1	39	32
17	1	39	32
18	1	39	32
19	1	39	32

* Percent.

B. MOBILE2.

The complete matrices of benefits described above are stored in MOBILE2. MOBILE2 has the capability to internally combine the I/M emission benefits resulting from all model years of vehicles (before and after the 1981 model year) and to arrive at a fleetwide figure of the percent benefit due to I/M in any given calendar year. A detailed description of how that is done will not be given in this report. Those readers interested in exactly how MOBILE2 applies I/M benefits to calculate a fleetwide figure can find a discussion of the basic concepts in the report which describes the derivation of I/M benefits for earlier model year fleets. (That report had not been released in final form at the time when this report was released, so an EPA identification number could not be referenced.)

C. The Default Case and Optional Cases.

The MOBILE2 default case for post-1980 vehicles includes a 50% identification rate of Primary category vehicles and full benefits from identifying vehicles with ignition/misfire problems. It is not possible for users of MOBILE2 to modify the ignition/misfire benefits. All I/M programs are assumed to be capable of identifying these vehicles. The rate of identification of Primary category vehicles can be modified, however. MOBILE2 contains benefits resulting from 60%, 70%, 80%, and 90% Identification Rates in addition to the default value of 50%. The 50% default value is currently associated with the use of the Idle(N) test. Users of MOBILE2 who wish to use other Identification Rates should be prepared to demonstrate that the rate they use can be achieved with a specific short test procedure and specific inspection standards. The Identification Rates are therefore related to specific short tests. This is in contrast to earlier model year benefits as calculated by MOBILE2 which vary based on stringency factors. Stringency factors are a function of HC and CO cutpoints.

D. Mechanic Training.

There are not assumed to be any incremental benefits from mechanic training for post-1980 vehicles. This is not because mechanic training is assumed to be of no importance for the post-1980 fleet. Rather it is due to the expected nature of repairs on these vehicles and their inability to pass an I/M retest if they have not been correctly repaired. Since post-1980 vehicles rely on a complex network of interactive electrical/mechanical components, the repair of Primary category vehicles is expected to rely chiefly on correct system diagnosis usually followed by component replacement or repair. Repairs are therefore expected to be largely of a component nature as opposed to the largely adjustment nature of repairs for more conventional technology vehicles (e.g. idle mixture adjustment, timing adjustment). One effect of this will be to make emission-related repairs much more of an all-or-none issue. It is assumed that a Primary category vehicle will either be successfully diagnosed and repaired with correspondingly low emissions (equal to Secondary or Misfueled vehicles) or it will be incorrectly diagnosed and incorrectly repaired with correspondingly very high emissions. An incorrectly repaired vehicle is unlikely to be able to pass an I/M retest. A similar logic prevails for repairs on vehicles with ignition/misfire problems. Repairs on

these vehicles are also largely of a component nature and the emission results of repair are also very much an all-or-none issue. Thus, there is not assumed to be a benefit resulting from mechanic training for post-1980 vehicles since a vehicle will not be able to pass the I/M test until the owner finds a mechanic who can correctly repair his vehicle.*

It may be the case that as more data on post-1980 vehicles becomes available, benefits for the identification and repair of Misfueling and Secondary category vehicles emitting above the standard may be practical and justifiable. At this point the available data is insufficient to support such an analysis and the effect is assumed to be small. Should this situation change, and Secondary and Misfueling category vehicles are also shown to contribute significant I/M benefits, mechanic training might also play more of a role for the post-1980 fleet.

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* EPA recommends that local I/M planners provide for and encourage mechanic training for post-1980 vehicles. This is to ensure an adequate number of trained mechanics to be able to handle the repairs generated by an I/M program as well as to help ensure competitively-based pricing in the repair marketplace.

References

1. "Derivation of 1981 and Later Light Duty Vehicle Emission Factors for Low Altitude, Non-California Areas", EPA-AA-IMS/80-8.

2. EPA Internal Memorandum; August 2, 1979; from Benjamin R. Jackson, Deputy Assistant Administrator, Mobile Source and Noise Enforcement, to all Regional Administrators.

Appendix A
I/M Short Test Data on Primary Category Vehicles

Vehicle Description	FTP* HC	FTP* CO	FTP* NOx	Short Test Modes (HC/CO)+ Idle(N)	2500 rpm	Idle(D)	30 mph	Idle(N)**
1980 Chevrolet Citation, 151 CID	4.79	178.50	0.10	159/5.42	227/7.24	193/5.69	318/9.56	145/5.03
1980 Chevrolet Citation, 171 CID	3.23	88.59	0.31	0/0	7/0.05	0/0	2/0.02	2/0.01
1980 Chevrolet Citation, 171 CID	2.38	82.61	0.32	2/0.02	20/0.13	137/3.10	11/0.37	5/0.03
1980 Chevrolet Citation, 151 CID	2.15	87.38	0.13	4/0.03	150/2.86	12/0.03	171/3.81	24/0.06
1980 Chevrolet Citation, 171 CID	4.64	120.31	0.81	16/0.07	17/0.05	173/4.89	216/5.52	184/6.18
1979 Mercury Marquis, 351 CID	3.07	50.49	1.25	560/7.9	160/2.5	593/1.4	150/0	90/0.2
1979 Mercury Marquis, 351 CID	3.26	65.64	0.79	2/0.01	35/1.18	118/0.16	179/2.41	391/0.57
1979 Ford Station Wagon, 351 CID	7.15	155.89	0.49	727/9.33	194/4.64	539/9.29	353/5.36	727/9.64
1979 Ford Station Wagon, 351 CID	3.90	126.27	1.07	278/4.61	84/3.56	230/5.46	160/3.97	274/4.54
1979 Mercury Marquis 351 CID	3.91	124.20	0.76	357/5.76	117/4.30	305/6.81	219/5.39	361/6.17

* FTP values are all in units of g/mi.
\+ Short Test values are in units of ppm for HC and % for CO.
** Idle(N) mode for the Loaded Two Mode test.

```
>      1      CC
>      1.2    CC
>      1.4    CC                                  APPENDIX B.
>      1.45   CC
>      1.5    CC
>      1.6    CC
>      2      CC
>      3      CC    THIS PROGRAM CALCULATES I/M BENEFITS FOR THE POST-1980 FLEET.
>      3.2    CC
>      3.4    CC
>      3.6    CC    ESTABLISH VARIABLES.
>      4      CC
>      5            REAL MZ, MA,INT
>      6            DIMENSION MILE(20), RATE(6),  EWO(20,2), EW(20,2), B(20,2)
>      7            DIMENSION  PZ(20,6),MZ(20,6),SZ(20,6), Y(20,6),INT(2)
>      8            DIMENSION  PA(20,6),MA(20,6),SA(20,6), G(20,6) ,  MDIF(20)
>      9      CC
>     10            DIMENSION EP(20,2),ES(20,2),EM(20,2),  CW(20,2),CZ(20,2),CA(20,2)
>     11            DIMENSION EPZ(20),ESZ(20),EMZ(20),  CZL(20,2),CAL(20,2)
>     12      CC
>     13      CC
>     13.2    CC    AVERAGE MILEAGE FOR I/M INSPECTION POINTS.
>     13.4    CC
>     13.6    CC
>     14            DATA MILE / 14436, 28339, 41710, 54548, 66854,
>     15           +            78627, 89867,100575,110751,120394,
>     16           +           129504,138081,146126,153639,160619,
>     17           +           167066,172993,178375,183225,187542/
>     17.1    CC
>     17.2    CC
>     17.3    CC    IDENTIFICATION RATES TO BE EXAMINED.
>     17.4    CC
>     17.5    CC
>     18            DATA RATE/ .5,  .6,  .7,  .8,  .9, 1.0 /
>     18.1    CC
>     18.2    CC
>     18.3    CC    WITHOUT-I/M EMISSION FACTOR INTERCEPTS (BOUNDARY CONDITION).
>     18.4    CC
>     18.5    CC
>     19            DATA INT/ 0.40 , 5.21 /
>     20      CC
>     21.2    CC
>     21.3    CC    CALCULATE MILEAGE BETWEEN INSPECTION POINTS.
>     21.4    CC
>     21.5    CC
>     22            MDIF(1) = 0
>     23            DO  5 I=2,20
>     24            MDIF(I) = MILE(I) - MILE(I-1)
```

```
>    25          5 CONTINUE
>    26      CC
>    26.1    CC
>    26.2    CC    SET EMISSION LEVELS FOR THE CATEGORIES (WITH-I/M).
>    26.3    CC
>    26.4    CC
>    27            DO 10 I=1,20
>    28            EP(I,1) =   3.74  +  0.000007 * MILE(I)
>    29            ES(I,1) =   0.23  +  0.000007 * MILE(I)
>    30            EM(I,1) =   1.05  +  0.000007 * MILE(I)
>    31            EP(I,2) = 107.36  +  0.000071 * MILE(I)
>    32            ES(I,2) =   1.86  +  0.000071 * MILE(I)
>    33            EM(I,2) =   4.24  +  0.000071 * MILE(I)
>    34      CC
>    34.1    CC
>    34.2    CC    WITHOUT-I/M COMPOSITE EMISSION LEVELS.
>    34.3    CC
>    34.4    CC
>    35            CW(I,1) = 0.40 + 0.19 * MILE(I) / 10000
>    36            CW(I,2) = 5.21 + 2.81 * MILE(I) / 10000
>    37            IF( I .EQ. 20 ) GO TO 10
>    37.1    CC
>    37.2    CC
>    37.3    CC    HC EMISSIONS BETWEEN INSPECTIONS (ALLOWS FOR THE CALCULATION OF
>    37.4    CC    IGNITION/MISFIRE BENEFITS).
>    37.5    CC
>    37.6    CC
>    38            EPZ(I+1) = EP(I,1) + .000012*MDIF(I+1)
>    39            ESZ(I+1) = ES(I,1) + .000012*MDIF(I+1)
>    40            EMZ(I+1) = EM(I,1) + .000012*MDIF(I+1)
>    41         10 CONTINUE
>    42      CC
>    42.1    CC
>    42.2    CC    HC EMISSIONS AT THE FIRST INSPECTION POINT (BOUNDARY CONDITION).
>    42.3    CC
>    42.4    CC
>    43            EPZ(1)=3.91
>    44            ESZ(1)=.40
>    45            EMZ(1)=1.22
>    46      CC
>    46.1    CC
>    46.2    CC    INITIALIZE THE CALCULATION OF BENEFITS FOR VARIOUS IDENTIFICATION RATES.
>    46.3    CC
>    46.4    CC
>    47            DO 200 J=1,6
>    48      CC
>    49      CC
>    49.1    CC    INITIALIZE CALCULATIONS FOR VARIOUS PROGRAM STARTUP YEARS
>    49.2    CC    (I.E. YEARS SINCE MODEL YEAR INTRODUCTION).
>    49.3    CC
>    49.4    CC
```

```
      DO 100 L=1,19
        IS = 20 - L
CC
      DO  60 I=1,IS
        M = L + I - 1
      IF( I.GT. 1 ) GO TO 2
CC
CC
CC    PRIMARY CATEGORY SIZE BEFORE AND AFTER INSPECTION.
CC
CC
      PZ(M,J) = .03 + MILE(M) * 2. / 1000000.
      PA(M,J) = ( 1. - RATE(J) ) * PZ(M,J)
      IF( M .EQ. 1 ) GO TO 2
      DO 20 K=1,2
   20 CA(M-1,K)=CW(M-1,K)
CC
CC
CC    LIKELIHOOD OF OCCURENCE AND GROWTH OF PRIMARY CATEGORY.
CC
CC
    2  Y(M,J) = .02 / ( .97 - 2.* MILE(M)/1000000.)
       G(M,J) = Y(M,J) * ( 1. - PA(M,J) )
CCC   IF( I.EQ. IS)  GO TO 4
CC
      PZ(M+1,J) =  PA(M,J)          + G(M,J)*( MDIF(M+1) )/10000.
      PA(M+1,J) =  PZ(M+1,J) -RATE(J)* G(M,J)*( MDIF(M+1) )/10000.
CC
CC
CC    MISFUELING CATEGORY SIZE BEFORE AND AFTER INSPECTION.
CC
CC
    4 MZ(M,J) =  .08 *( 1. - PZ(M,J) )
      MA(M,J) =  .08 *( 1. - PA(M,J) )
CC
CC
CC    SECONDARY CATEGORY SIZE BEFORE AND AFTER INSPECTION.
CC
CC
      SZ(M,J) = 1.00 - PZ(M,J) - MZ(M,J)
      SA(M,J) = 1.00 - PA(M,J) - MA(M,J)
CC
CC
CC    COMPOSITE EMISSIONS BEFORE AND AFTER INSPECTION.
CC
CC
      CZ(M,1) =  PZ(M,J)*EPZ(M)  + SZ(M,J)*ESZ(M)  + MZ(M,J)*EMZ(M)
      CZ(M,2) =  PZ(M,J)*EP(M,2) + SZ(M,J)*ES(M,2) + MZ(M,J)*EM(M,2)
CC
      CA(M,1) =  PA(M,J)*EP(M,1) + SA(M,J)*ES(M,1) + MA(M,J)*EM(M,1)
      CA(M,2) =  PA(M,J)*EP(M,2) + SA(M,J)*ES(M,2) + MA(M,J)*EM(M,2)
```

```
C
C
   60 CONTINUE
C
C
C     EMISSIONS AT THE 20TH YEAR (BOUNDARY CONDITION).
C
C
      MZ(20,J) = .08 * (1.-PZ(20,J))
      SZ(20,J) = 1.0 - PZ(20,J) - MZ(20,J)
      CZ(20,1) = PZ(20,J)*EPZ(20) + SZ(20,J)*ESZ(20) + MZ(20,J)*EMZ(20)
      CZ(20,2) = PZ(20,J)*EP(20,2) + SZ(20,J)*ES(20,2) + MZ(20,J)*EM(20,2)
C
C
      DO 70 I=1,IS
      M=L+I-1
C
C
C     CALCULATE BENEFITS BY COMPARING EMISSIONS WITH AND WITHOUT I/M ON JANUARY 1ST. DATES.
C     SINCE MODEL YEAR INTRODUCTION IS ON OCTOBER 1ST., THIS REQUIRES A 75/25 STAGGERING.
C
C
C
      DO 35 K=1,2
      IF(L .GT. 1) GO TO 36
      IF( M .EQ. 1 ) GO TO 34
       EWO(M,K) = .75 *(.625*CW(M,K)+ .375*CW(M-1,K)  )
     +          + .25 *(.875*CW(M,K)+ .125*CW(M+1,K)  )
C
       EW (M,K) = .75 *(.625*CZ(M,K)+ .375*CA(M-1,K)  )
     A          + .25 *(.875*CA(M,K)+ .125*CZ(M+1,K)  )
C
      GO TO 33
   34 EW(1,K) = .75 *(.625*CZ(1,K) + .375*INT(K))
     +         + .25*(.875*CA(1,K)+ .125*CZ(2,K)  )
      EWO(1,K)= .75 *(.625*CW(1,K) + .375*INT(K))
     +         + .25*( .875*CW(1,K) + .125*CW(2,K))
      GO TO 33
   36 EW(M,K) = .75*(.625*CZL(M,K) + .375*CAL(M-1,K))
     +          +.25*(.875*CA(M,K)    + .125*CZ(M+1,K))
       EWO(M,K) = .75 *(.625*CW(M,K)+ .375*CW(M-1,K)  )
     +          + .25 *(.875*CW(M,K)+ .125*CW(M+1,K)  )
   33  B  (M,K) = 100.*(EWO(M,K) - EW(M,K))/ EWO(M,K)
C
C
   35 CONTINUE
C
      WRITE(6,600) J,L,I, MILE(M), ((EWO(M,K),EW(M,K),B(M,K)),K=1,2),
     W              RATE(J)
  600 FORMAT(1X,3I4, I8,8F10.3)
C
   70 CONTINUE
```

```
>   124.1   CC
>   124.2   CC
>   124.3   CC    BOUNDARY CONDITION.
>   124.4   CC
>   124.5   CC
>   125           DO 75 K=1,2
>   126           DO 75 I=1,IS
>   127           M=L+I-1
>   128           CAL(M,K)=CA(M,K)
>   129        75 CZL(M,K)=CZ(M,K)
>   130       100 CONTINUE
>   131     CC
>   132     CC
>   133     CC
>   134     CC
>   135       200 CONTINUE
>   136     CC
>   137           STOP
>   138           END
```